MadGraph5

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UIUC

What do We need?

NLO

Exp-TH communication

Very exotic models

Multi-jet samples

Exotic models

Effective theories

Decay chains

Matrix Elements

Advanced analysis techniques

Real corrections

Decay Packages

Merging ME/PS

Cluster/Grid computing

User friendliness

Testing/robustness

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From Theory to Detector

Lagrangian

Detector events

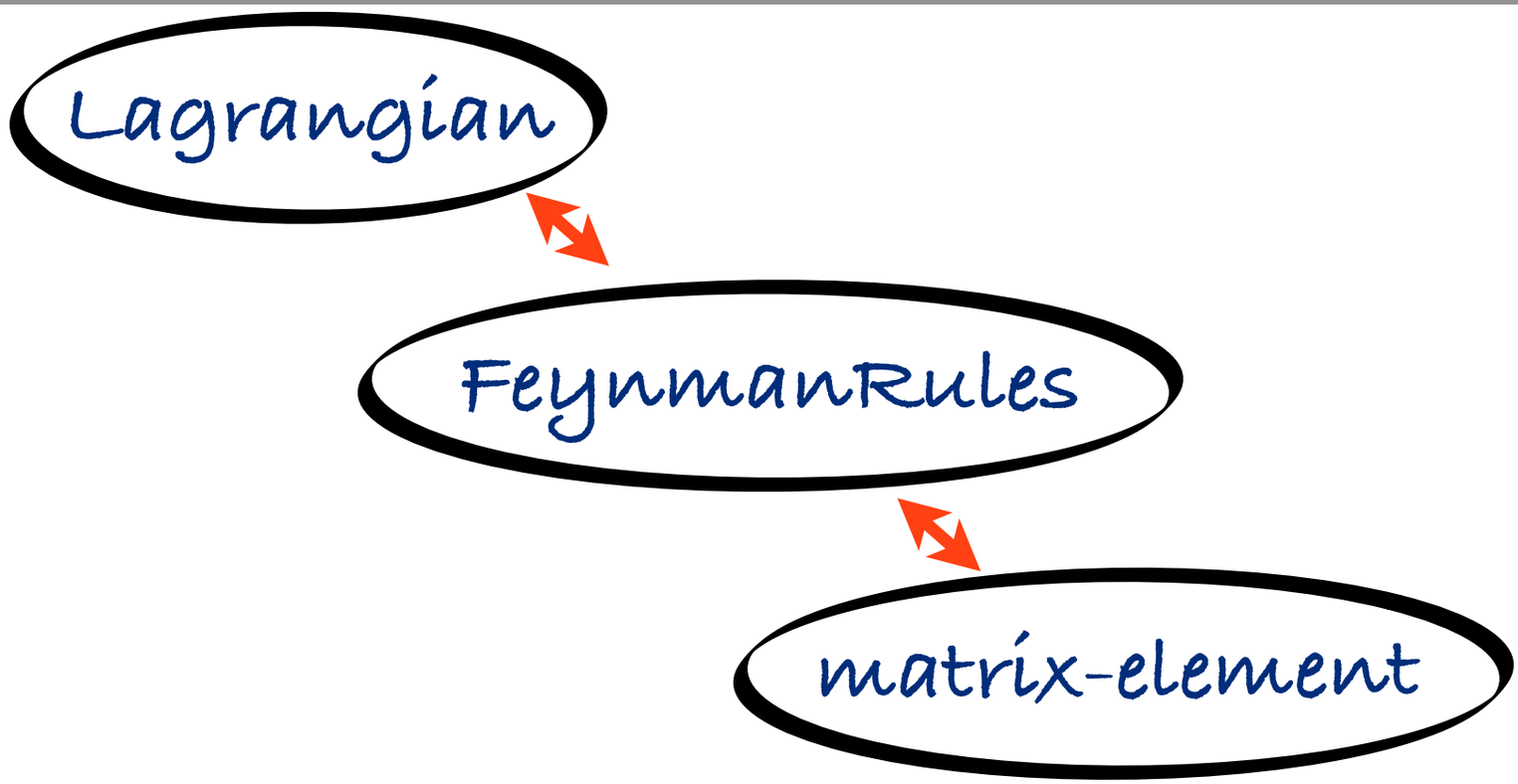
From Theory to Detector

Lagrangian

FeynmanRules

Detector events

From Theory to Detector



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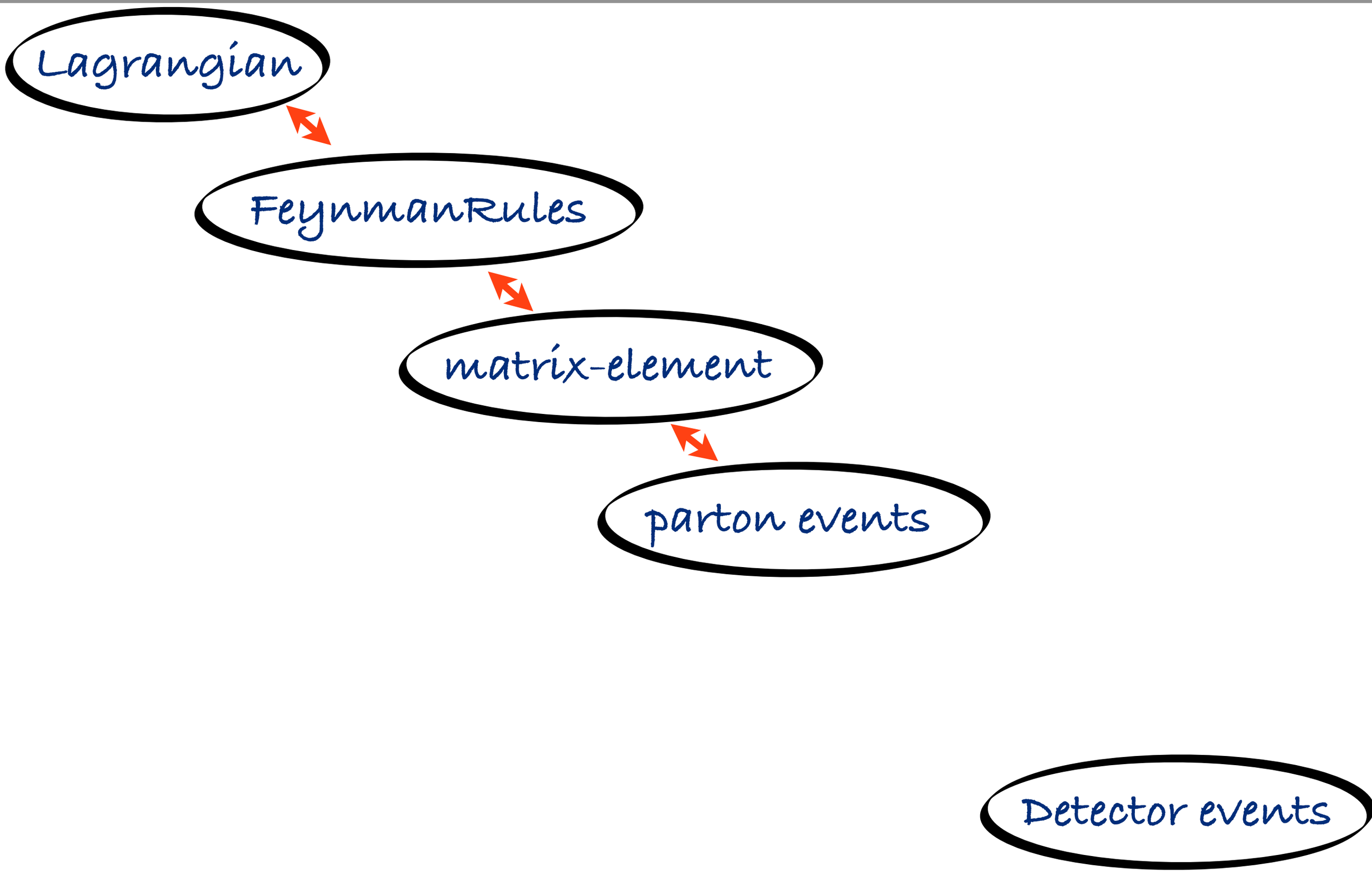

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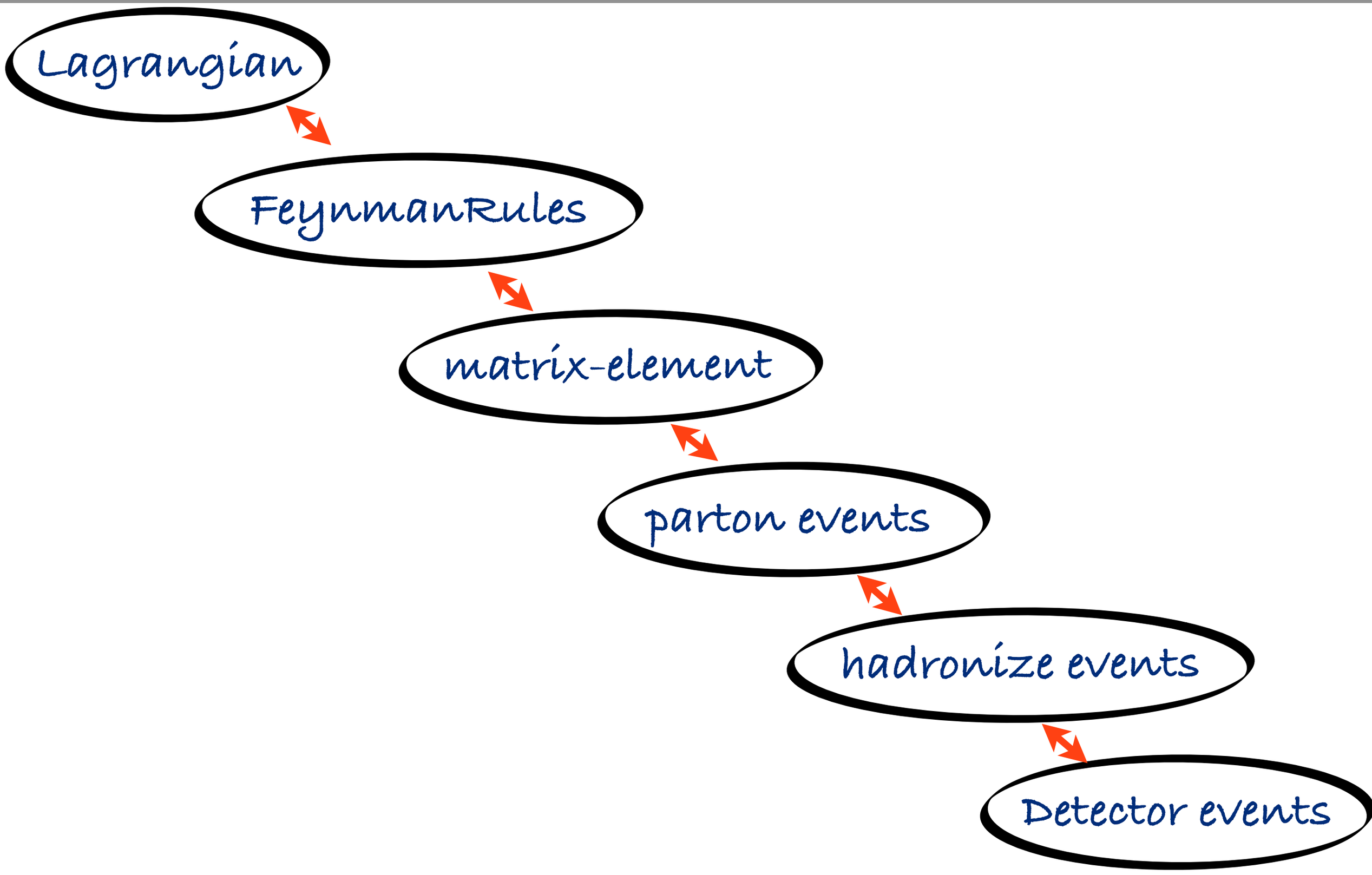

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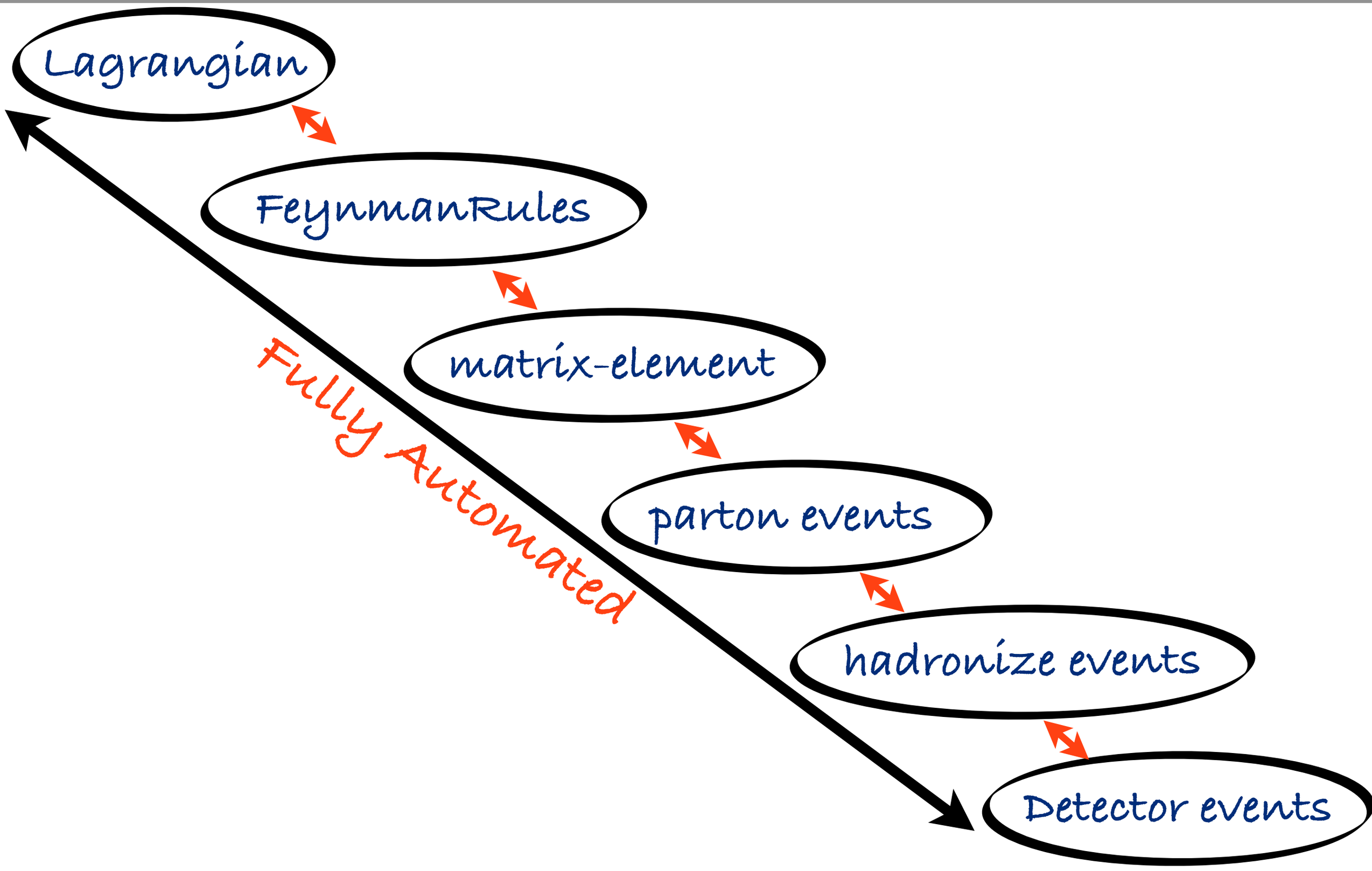

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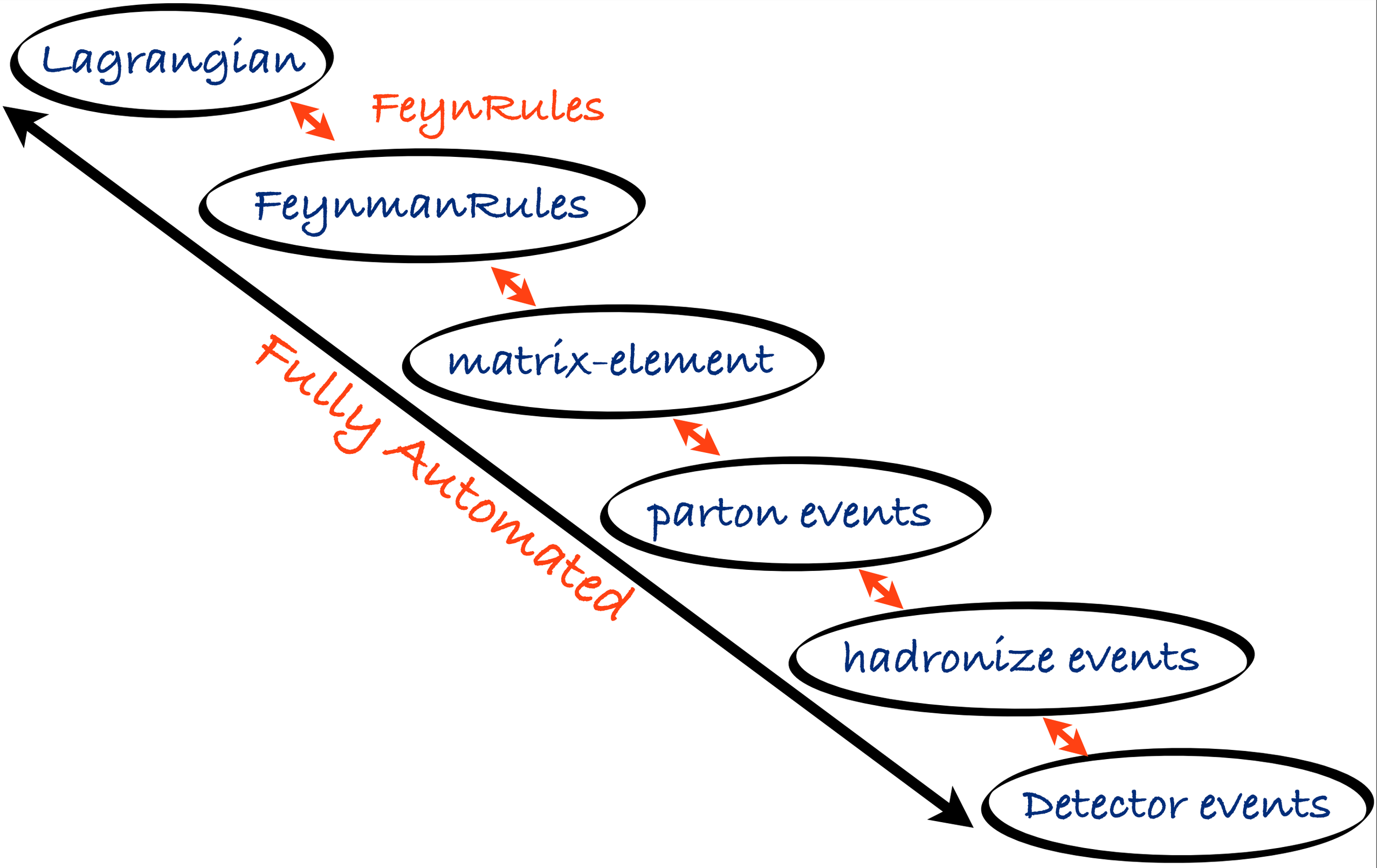

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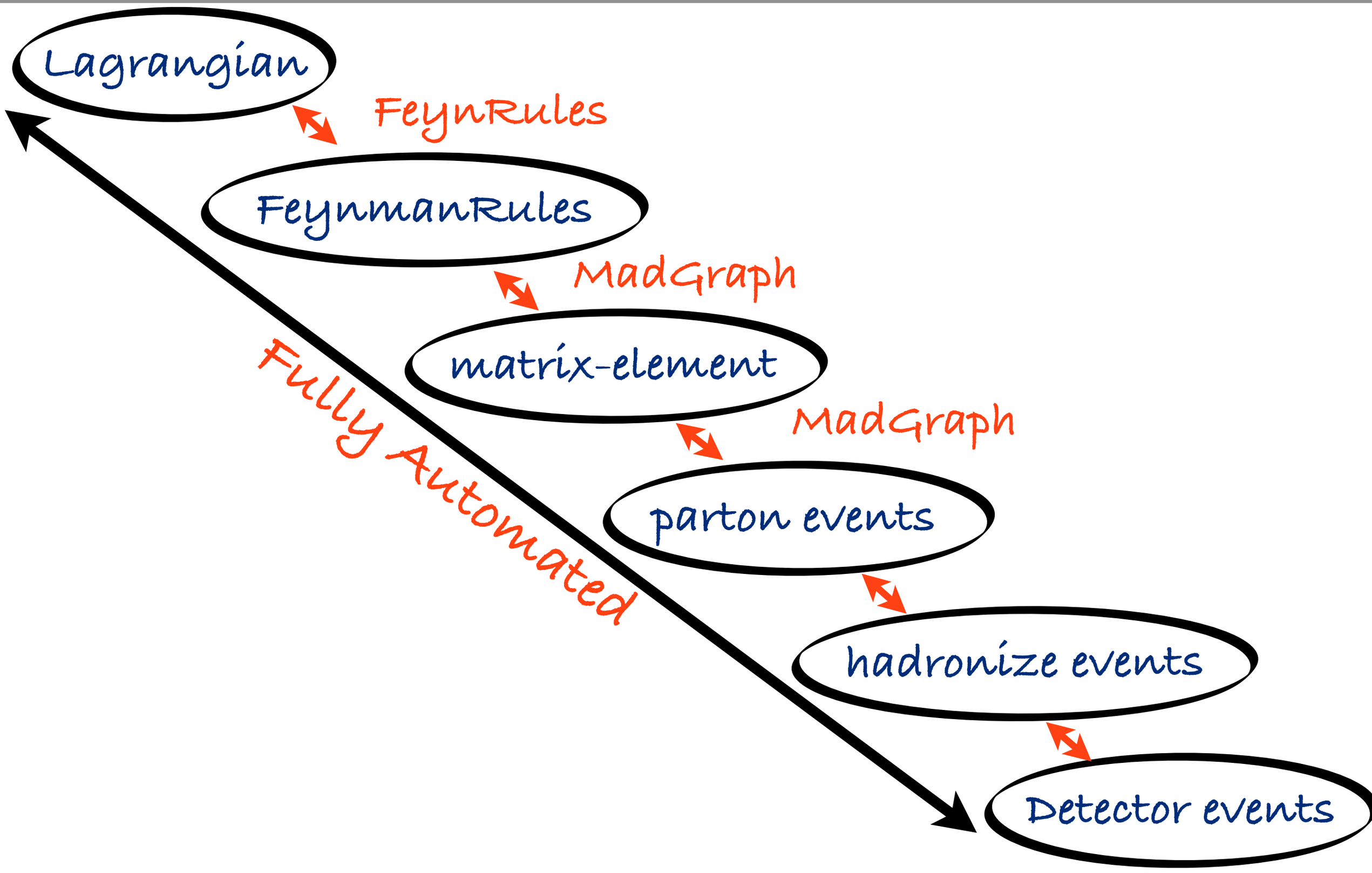

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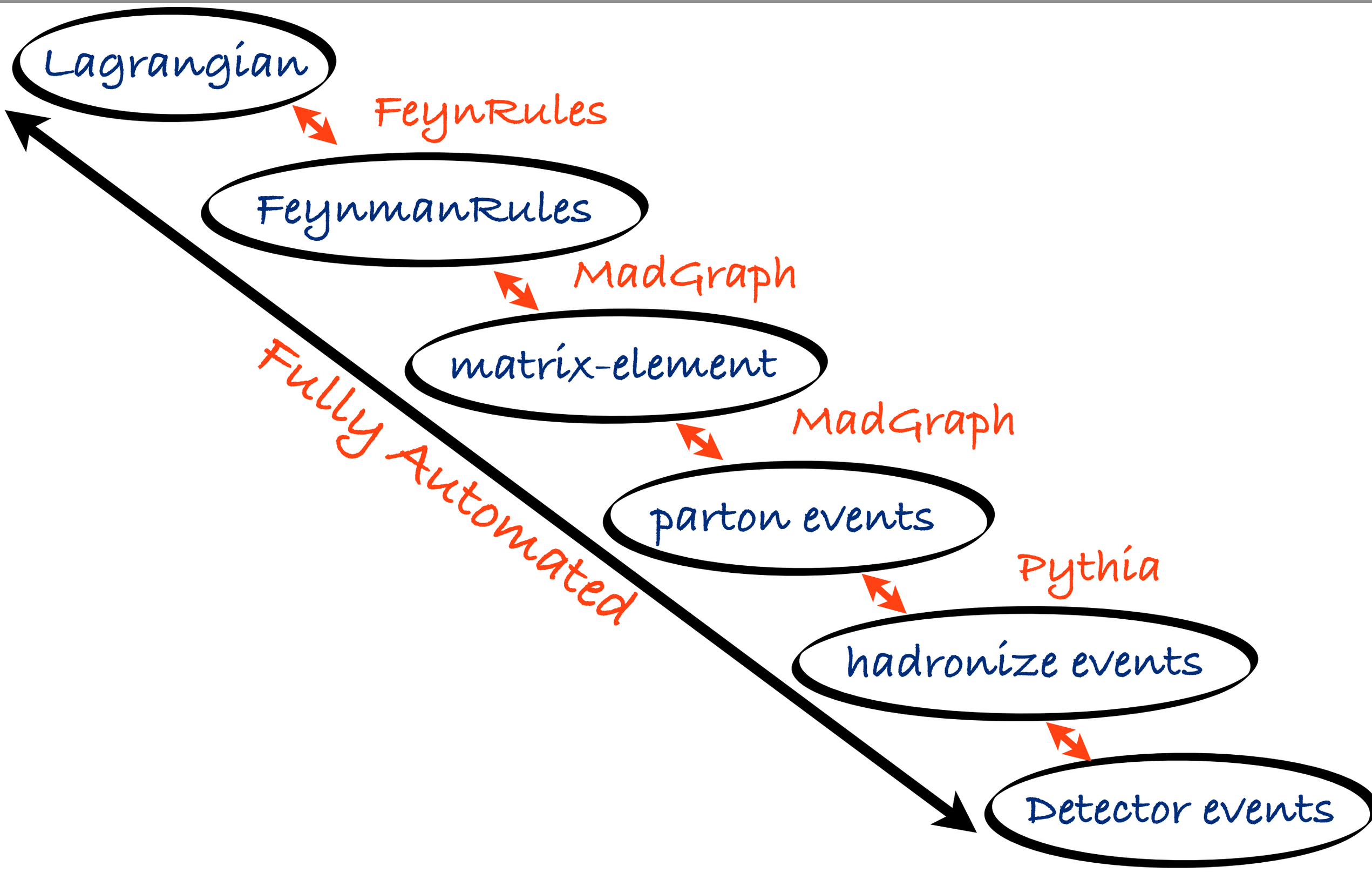

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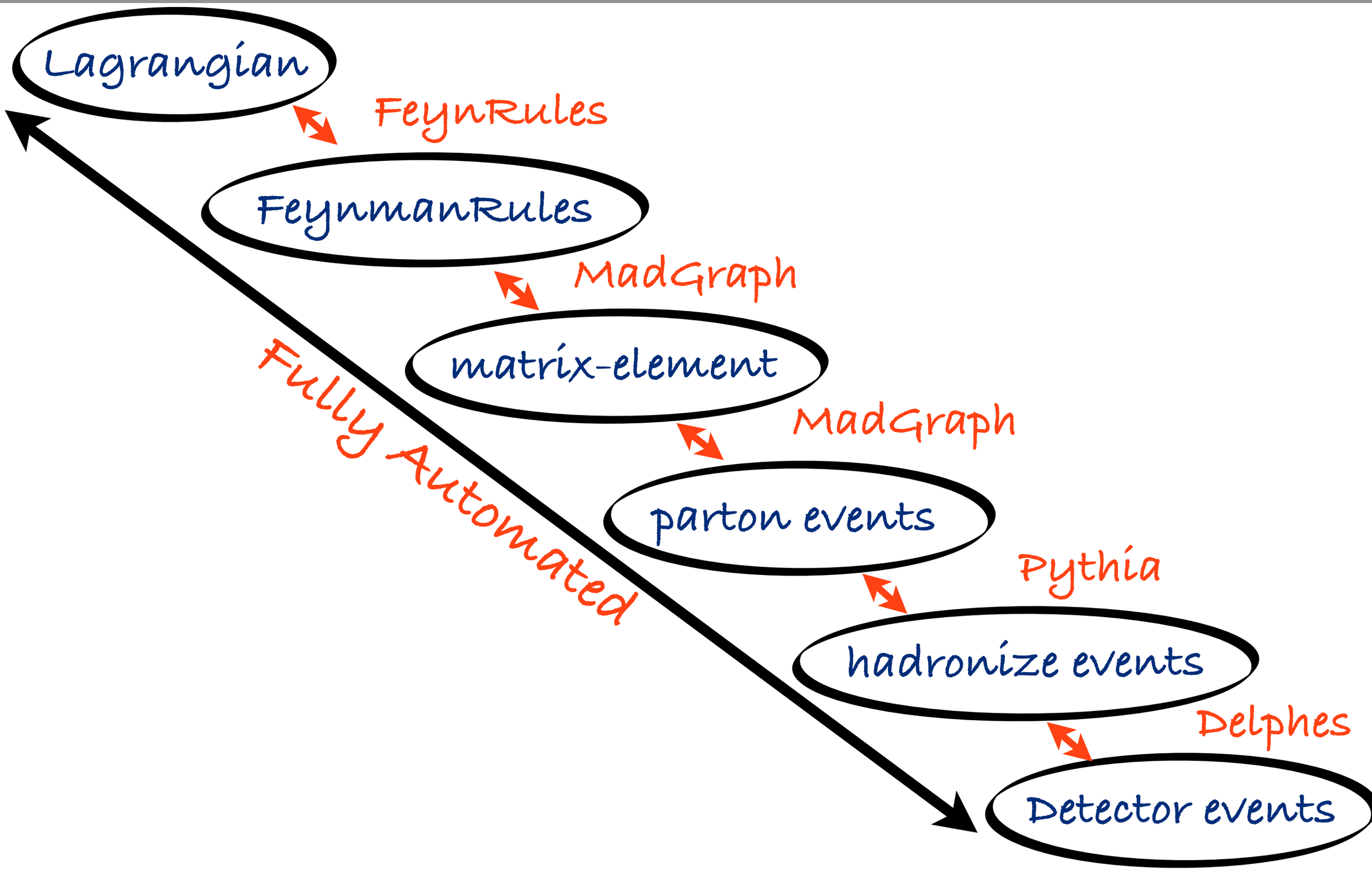

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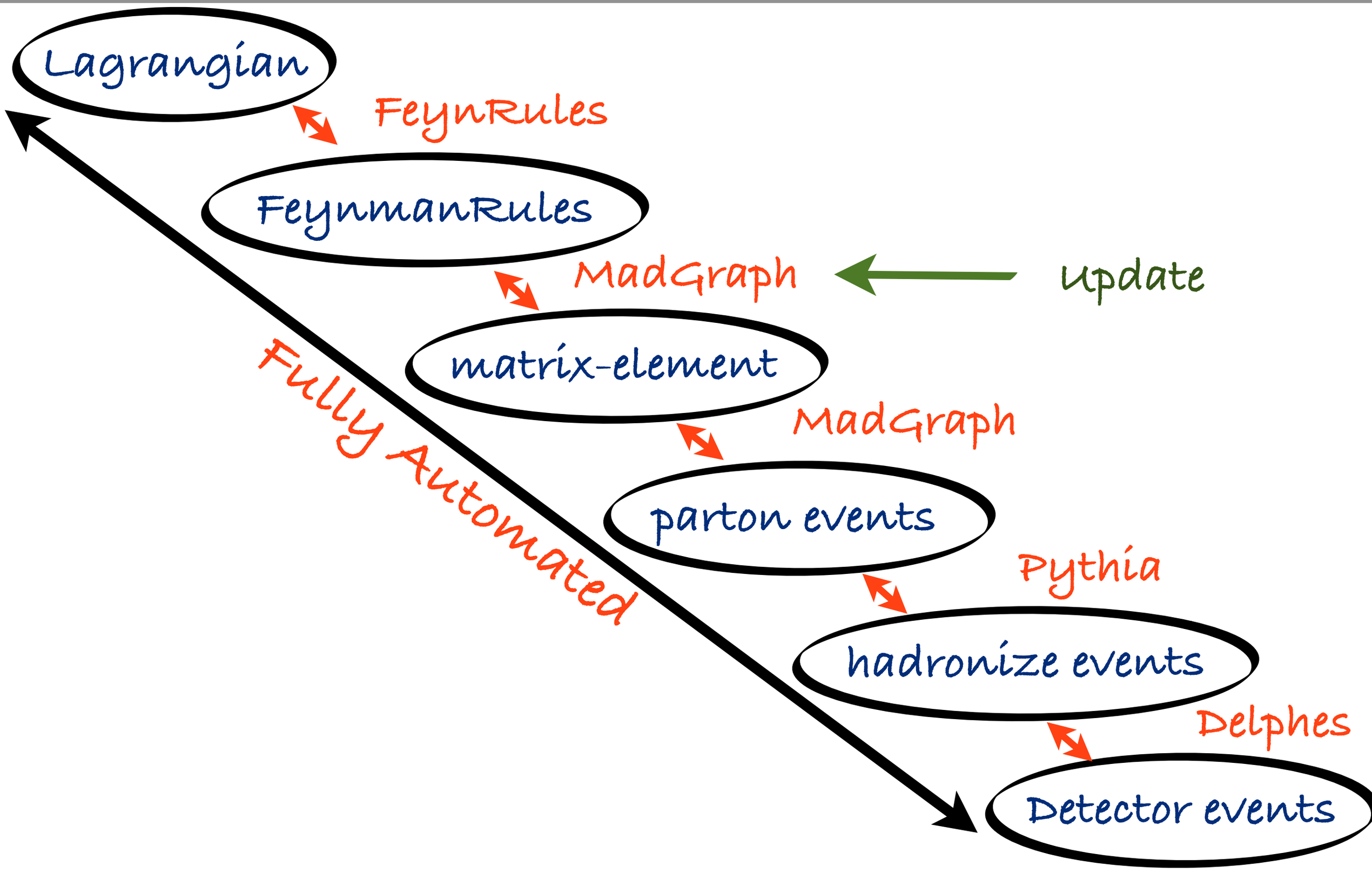

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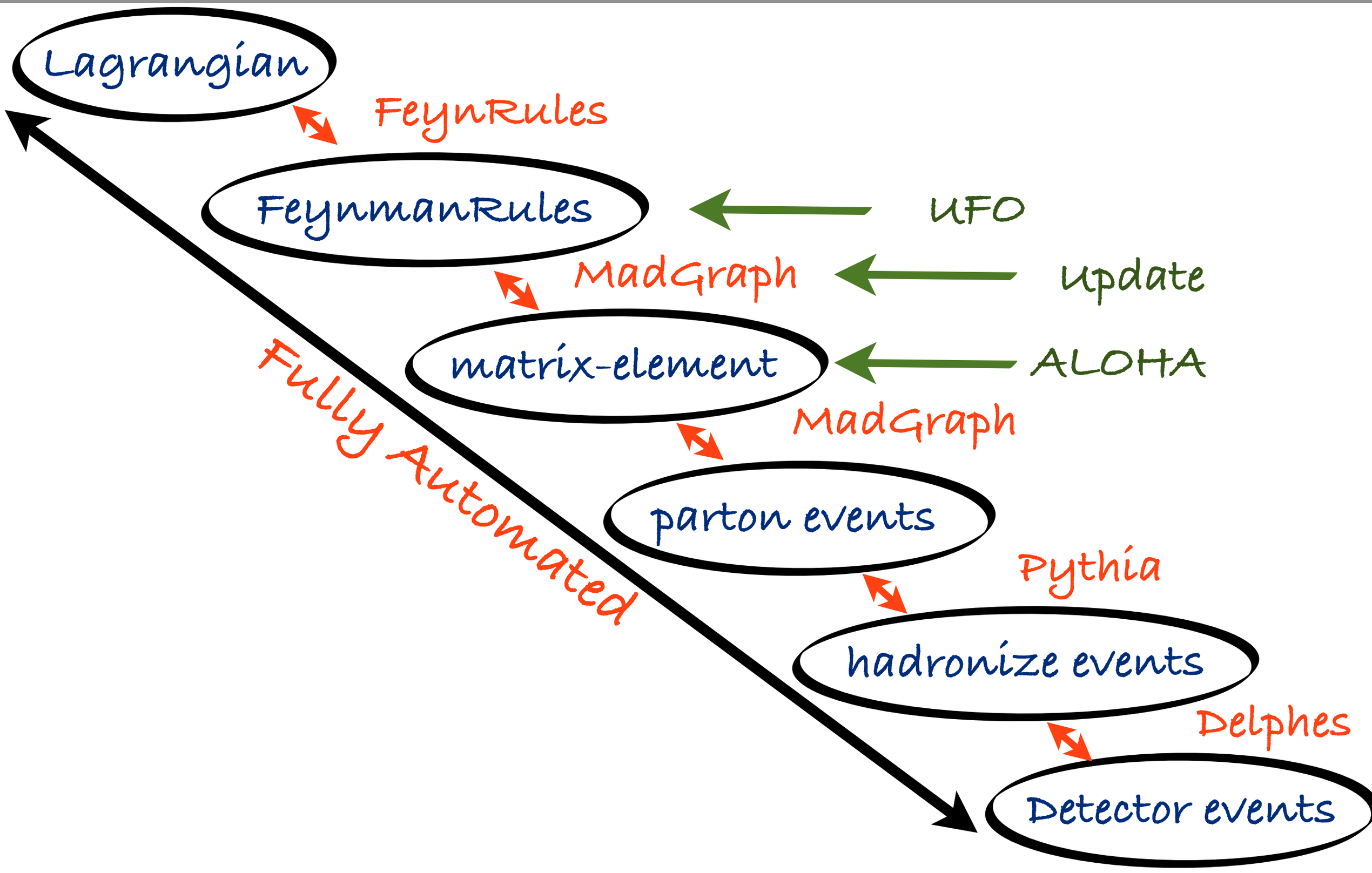

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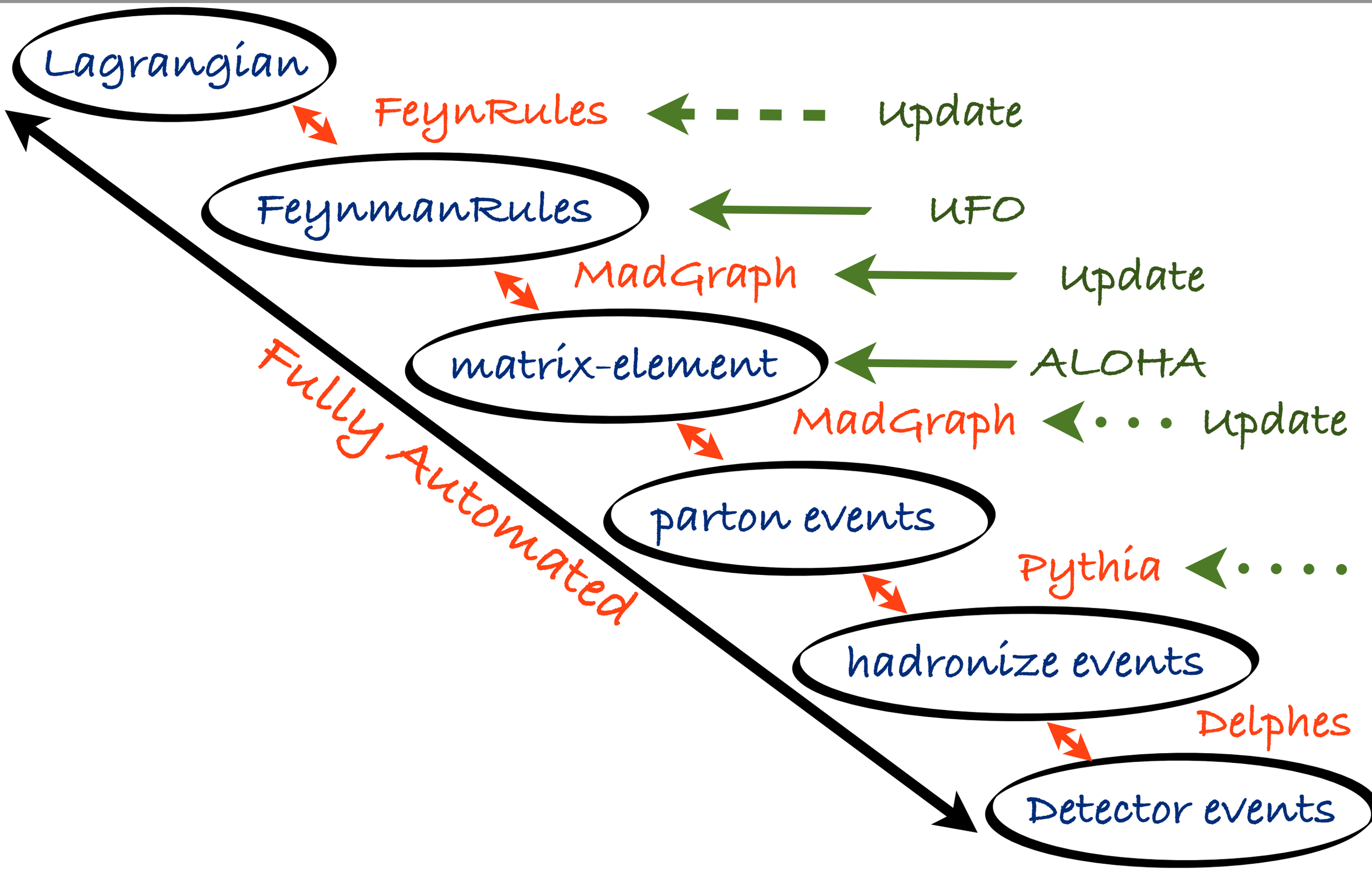

PLAN

- ☐ What do we want to improve
- ☐ UFO and ALOHA
- ☐ Present status of MadGraph5
- ☐ Long term development of MadGraph5

Why Change?

Why Change?

- True effective theory

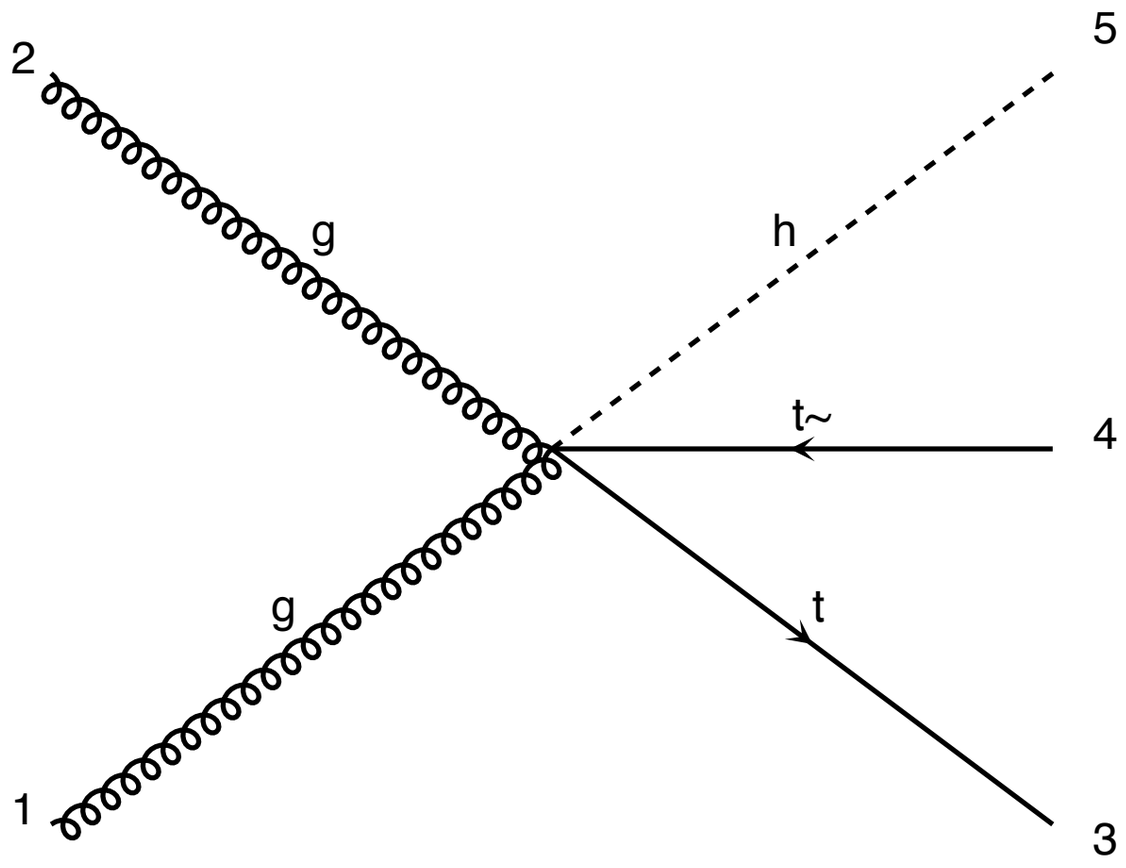

diagram 1

Why Change?

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- New color structure (6, epsilon)

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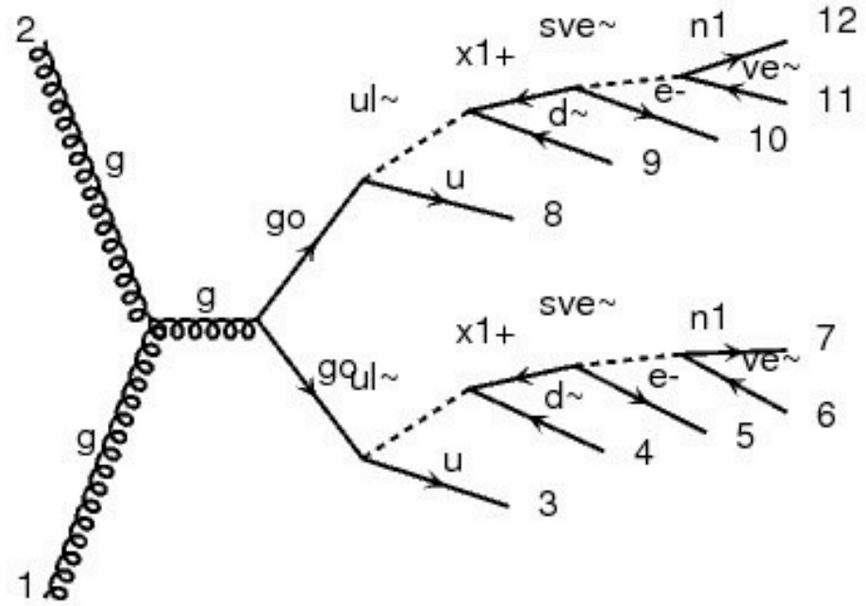

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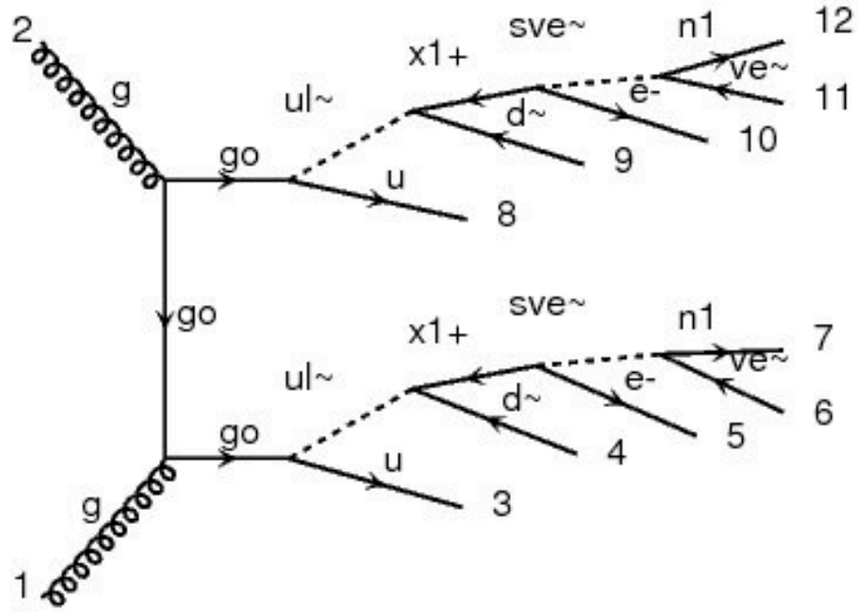

diagram 2

Why Change?

- True effective theory
- New color structure (6, epsilon)
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- Efficient decay chains
- C(++) output

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Why not MadGraph4.5?

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Why not MadGraph4.5?

- Code written in fortran 77
  - (memory issue / not object oriented / ...)
- Old code
  - No place for fast and efficient improvment

Time for a New Start

- ~~HARDER~~:
  - intuitive interface
- BETTER:
  - For Any Model
- FASTER:
  - For diagram generation
  - For generating events
- STRONGER:
  - extreme programming

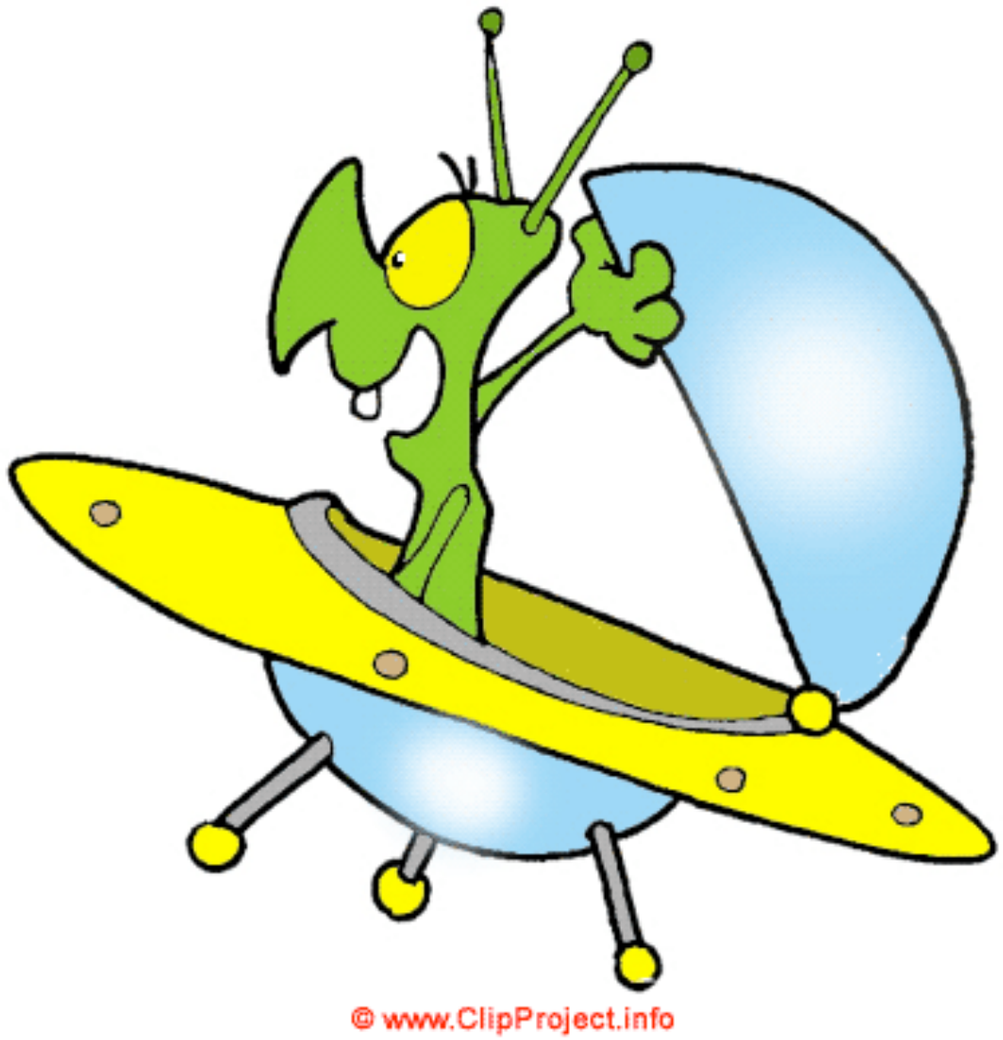
UFO and ALOHA

UFO

[Duhr et al]

UFO = Universal Feynrules Output

- joint format for
  - MadGraph5
  - Golem
  - Herwig++
- includes color
- includes lorentz
- Model in Python
- Object oriented



ALOHA

[P. De Aquino, W. Link, O.M]

ALOHA = Automatic Language-independent Output of Helicity Amplitudes.

- Lorentz → HELAS

$$\gamma^\mu \longrightarrow -i\, W_f(e^-)\, \gamma^\mu\, W_f(e^+)\, A_\mu \qquad \text{(IOV)}$$

$$\longrightarrow W_f(e^-)\, \gamma^\mu\, W_f(e^+)\, \frac{-i\,\eta_{\mu\nu}}{p_A^2} \qquad \text{(JIO)}$$

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$$\longrightarrow W_f(e^-)\, \gamma^\mu\, W_f(e^+)\, \frac{-i\,\eta_{\mu\nu}}{p_A^2} \qquad \text{(J10)}$$

```
FFV1 = Lorentz(name = 'FFV1',
               spins = [ 2, 2, 3 ],
               structure = 'Gamma(3,2,1)')
```

```
VERTEX = C*( (F2(1)*( (F1(3)*( (0, -1)*V3(1)+(0, 1)*V3(4)))
$ +(F1(4)*( (0, 1)*V3(2)+V3(3)))))+( (F2(2)*( (F1(3)*( (0, 1)
$ *V3(2)-V3(3)))+(F1(4)*( (0, -1)*V3(1)+(0, -1)*V3(4)))))
$ +( (F2(3)*( (F1(1)*( (0, -1)*V3(1)+(0, -1)*V3(4)))+(F1(2)
$ *( (0, -1)*V3(2)-V3(3)))))+(F2(4)*( (F1(1)*( (0, -1)*V3(2)
$ +V3(3)))+(F1(2)*( (0, -1)*V3(1)+(0, 1)*V3(4)))))))
```

ALOHA

[P. De Aquino, W. Link, O.M]

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- Spin 2 in progress (3/2 planned)
- The Helas routine for BSM without the pain to write it.
- Module install in MadGraph5 (not restricted to MG5)

MADGRAPH 5

MG5 INNOVATION

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- Completely new diagram generation algorithm
  - Makes Optimal use of Model information
  - Improves Helas call optimization by up to 90%

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u u~ > d d~ g g	0.42 ms	0.34 ms	0.24 ms
u u~ > d d~ d d~	0.12 ms	0.11ms	0.12 ms
u u~ > d d~ d d~ g g	141 ms	34.4 ms	19.6 ms

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- Generic new color calculation library

Status of MadGraph5

Beta 0.5.0

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Leading order Matrix Element generation	No Limitation (but time) W + 5 jets realistic

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Majorana treatment	YES

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MG4 retro-compatibility	100 %

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Automatic Helas	YES
Majorana treatment	YES
four fermion	V5.0.0 ?
MG4 retro-compatibility	100 %
Output Language	Fortran / C++
interactive mode	YES (with tutorial/help)

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Output for PYTHIA	YES

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Output for PYTHIA	YES
MadGraph StandAlone C++	BETA 0.6.0

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Optimised Multi-Channel	V5.0.0

Status of MadGraph5

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Output for PYTHIA	YES
MadGraph StandAlone C++	BETA 0.6.0
Optimised Multi-Channel	V5.0.0
Fast Diagram Drawer	YES

Status of MadGraph5

Beta 0.5.0

Output for PYTHIA	YES
MadGraph StandAlone C++	BETA 0.6.0
Optimised Multi-Channel	V5.0.0
Fast Diagram Drawer	YES
Test Suite	YES

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Optimised Multi-Channel	V5.0.0
Fast Diagram Drawer	YES
Test Suite	YES
Process checks on demand	YES(Gauge/Lorentz/Helas)

```
gauge results:
Process              matrix              BRS                 ratio               Result
g g > u u~ e+ e- 1.0425612398e-11 6.5208585466e-44 6.2546527699e-33 Passed
g g > d d~ e+ e- 5.0109015881e-13 1.7736391359e-41 3.5395609047e-29 Passed
Summary: 2/2 passed, 0/2 failed
lorentz invariance results:
Process              Min element       Max element       Relative diff.    Result
g g > u u~ e+ e-  2.1607379231e-12 2.1607379231e-12 1.3084777446e-15 Passed
g g > d d~ e+ e-  1.3886952867e-12 1.3886952867e-12 2.0068389608e-14 Passed
u u > u u e+ e-   9.1467101650e-13 9.1467101650e-13 2.6494560964e-15 Passed
u u~ > c c~ e+ e- 4.3734288472e-12 4.3734288472e-12 6.5754930485e-14 Passed
```

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MadWeight / MadOnia	V5.1.0

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Fast Diagram Drawer	YES
Test Suite	YES
Process checks on demand	YES (Gauge/Lorentz/Helas)
MadWeight / MadOnia	V5.1.0
More Features	V5.1.0

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Optimised Multi-Channel	V5.0.0
Fast Diagram Drawer	YES
Test Suite	YES
Process checks on demand	YES (Gauge/Lorentz/Helas)
MadWeight / MadOnia	V5.1.0
More Features	V5.1.0
Your Favorites features	V5.0.X

SPEED

Time to generate the square matrix-element for MadEvent

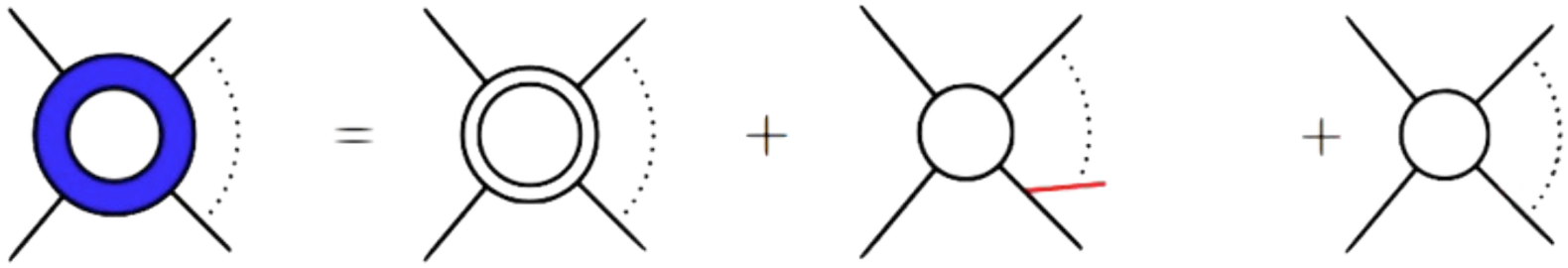
Process	MadGraph 4	MadGraph 5	Subprocesses	Diagrams
$pp \to jjj$	29.0 s	54.4 s	34	307
$pp \to jjl^+l^-$	341 s	258 s	108	1216
$pp \to jjje^+e^-$	1151 s	654 s	141	9012
$u\bar{u} \to e^+e^-e^+e^-e^+e^-$	772 s	175 s	1	3474
$gg \to ggggg$	2788 s	1049 s	1	7245
$pp \to jj(W^+ \to l^+\nu_l)$	146 s	70 s	82	304
$pp \to t\bar{t}$+full decays	5640 s	22 s	27	45
$pp \to \tilde{q}/\tilde{g}\,\tilde{q}/\tilde{g}$	222 s	286 s	313	475
7 particle decay chain	383 s	5.2 s	1	6
$gg \to (\tilde{g} \to u\bar{u}\tilde{\chi}_1^0)(\tilde{g} \to u\bar{u}\tilde{\chi}_1^0)$	70 s	5.5 s	1	48
$pp \to (\tilde{g} \to jj\tilde{\chi}_1^0)(\tilde{g} \to jj\tilde{\chi}_1^0)$	$\gg$ 1 year	551 s	144	11008

Future of MADGRAPH 5

Plan in MG5

- NLO Computations

NLO Virtual Real Born



$$\sigma^{\mathrm{NLO}} = \int_m d^{(d)}\sigma^V + \int_{m+1} d^{(d)}\sigma^R + \int_m d^{(4)}\sigma^B$$

MG5 = CutTools + MadFKS + MadGraph

CutTools: [V. Hirschi, R. Pittau, M. V. Garzielli, R. Frederix]

MadFKS: [R. Frederix, S. Frixione et al.]

Plan in MG5

- NLO Computations
- Recursive Relations
  - For multijet generation (≳ 4 jets), Feynman diagram formalism expensive (factorial growth)
  - Recursion relations (such as Berhrends-Giele) can reduce run time by orders of magnitude

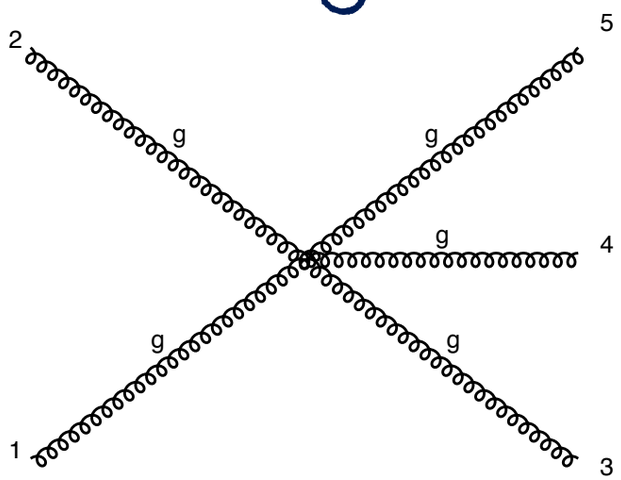


diagram 1

Conclusion

- MG/ME V4 is a mature, well established and stable code with many features for BSM and QCD physics and numerous peripheral tools
- MG5 is available with important and unprecedented improvements in all directions.
- Still many new features to come in the near future
- https://launchpad.net/madgraph5